D. A. Brandt ... 733

FINAL REPORT

FOR

IMAGE DISSECTOR CAMERA SYSTEM

(2 June 1965 - 16 August 1967)

Contract No. NAS5-9619

Prepared by

ITT Industrial Laboratories
Fort Wayne, Indiana 46806

For

Goddard Space Flight Center
Greenbelt, Maryland

ITTIL No. 67-1051 October 20, 1967

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1.0 INTRODUCTION

The Image Dissector Camera System (IDCS) was developed under Contract NAS5-9619 to provide daytime cloud cover pictures of the earth from the NIMBUS B spacecraft. This final report covers the major events during 27 months of camera development. These events involve a general working description, study phase, plan or concept period, Engineering Model, Prototype Model, First Flight Model, Second Flight Model, summary of camera characteristics and final drawing and diagrams.

This development program began June 2, 1965 and was completed in September 1967. After delivery of all models in August 1967, a problem in high voltage glow discharge in a test sample was discovered. FT03 and FT04 were subsequently returned to Ft. Wayne and reworked under contract NAS5-10155. Section 3.5 of this report describes this work.

Prior to the award of the subject contract, ITTIL performed a feasibility study under Contract NAS5-3770 using a 1.5 inch image dissector. The final report dated November 13, 1964 will provide background information. Figure 4 shows the program status over the entire 27 months.

2.0 GENERAL DESCRIPTION

The Image Dissector Camera System (IDCS) utilizes an ITTIL Vidissector with a wide angle lens which, from an orbital altitude of 600 nautical miles, will provide continuous daylight cloud cover and geographic pictures of a 1620 by 1620 nautical miles area. The system is completely electronic.

The system operates in an automatic mode, controlled by the spacecraft which turns on the IDCS during the daytime portion of the polar orbit and varies video signal gain. Backup modes of preset gain and power on/off may be commanded from ground stations.

Basic physical and electrical characteristics of the camera include overall dimensions of 17 x 5 x 6 inches, weight of 13 pounds, and 13 watts input power when operating at a nominal input of -24.5 volts dc. Figures 1 and 2 show the packaging and final form.

The camera interfaces with existing APT transmitting and receiving equipment which has a format consisting of a 3 second start tone followed by 5 seconds of phasing signal, followed by 200 seconds of picture information. Since the Vidissector contains a non-storage photocathode no shutter mechanism is used and the signal received is the image on the photocathode at the time of receipt. Each picture consists of 800 lines and the line rate is 4 Hz.

The camera operates with scene brightness ranging from 10,000 to 100 foot lamberts with a signal-to-noise ratio at the lower illumination of 20 db. At the planned altitude, the raster to be scanned on the Vidissector photocathode is 0.518 inch by 0.336 inch, and resolution of the earth at the raster center is 1.73 nautical miles. Due to the curvature of the earth the edge resolution is 6.651 nautical miles.

The heart of the camera system is the Vidissector and its photocathode, for it defines the spectral response, the maximum allowable illumination, the output signal-to-noise ratio, and the camera useful lifetime.

The selected photocathode, having an S11 response, has a peak response to 0.44 micron with skirts down to 10 percent at 0.62 and 0.30 micron. Photons striking the photocathode cause a photoemission of electrons which are accelerated by the mesh toward the drift tube space. Within the drift tube these electrons, now at constant velocity, are electro-magnetically focused to form an electron image at the aperture plate, identical to the optical image focused upon the photocathode. Using deflection coils, the focused electron image at the aperture is sequentially scanned by a 0.001 inch circular aperture in such a manner as to divide the image into 800 elements/line and 800 lines/frame within the allotted 200 seconds.

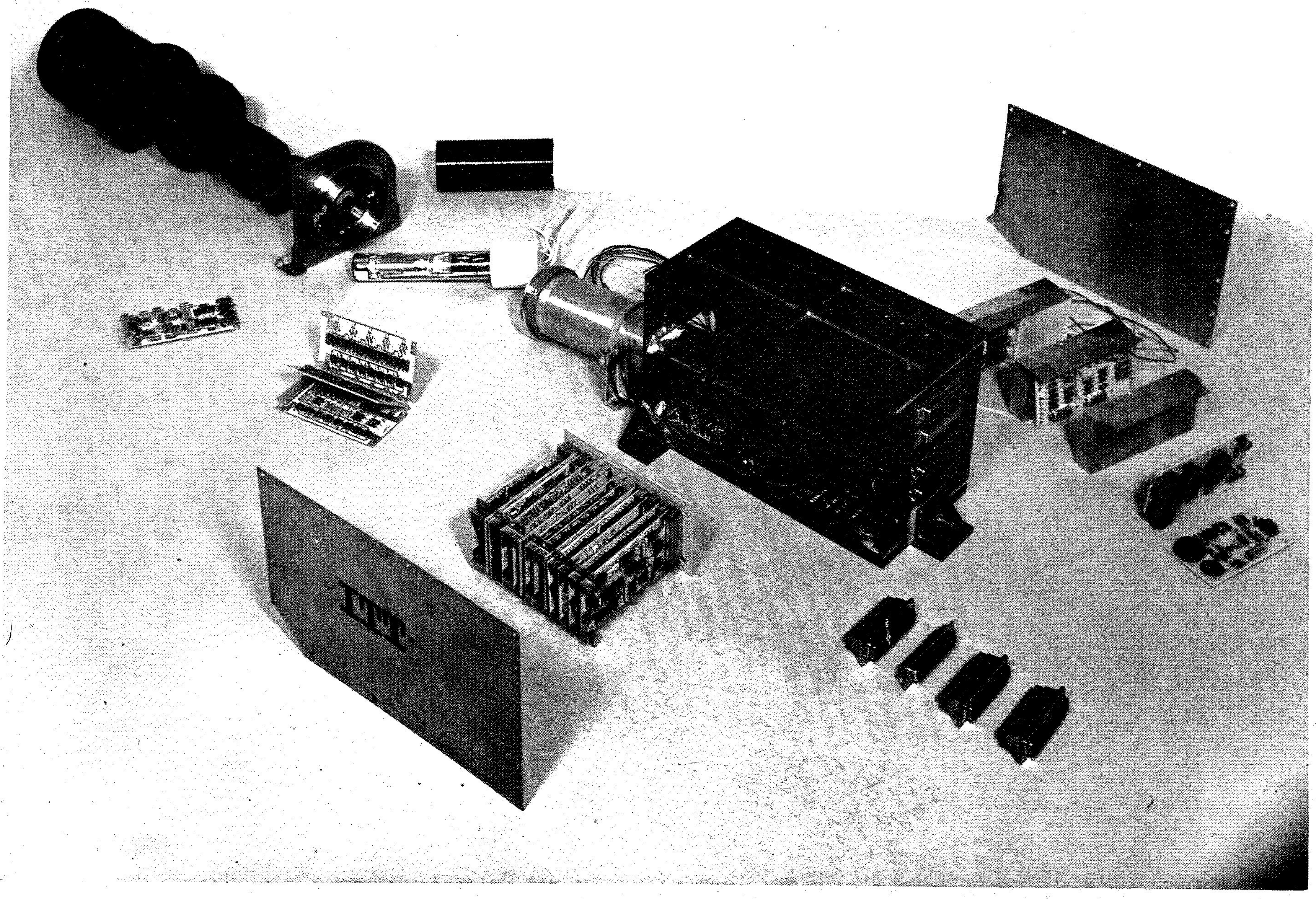


Figure 1 Camera (Exploded View)

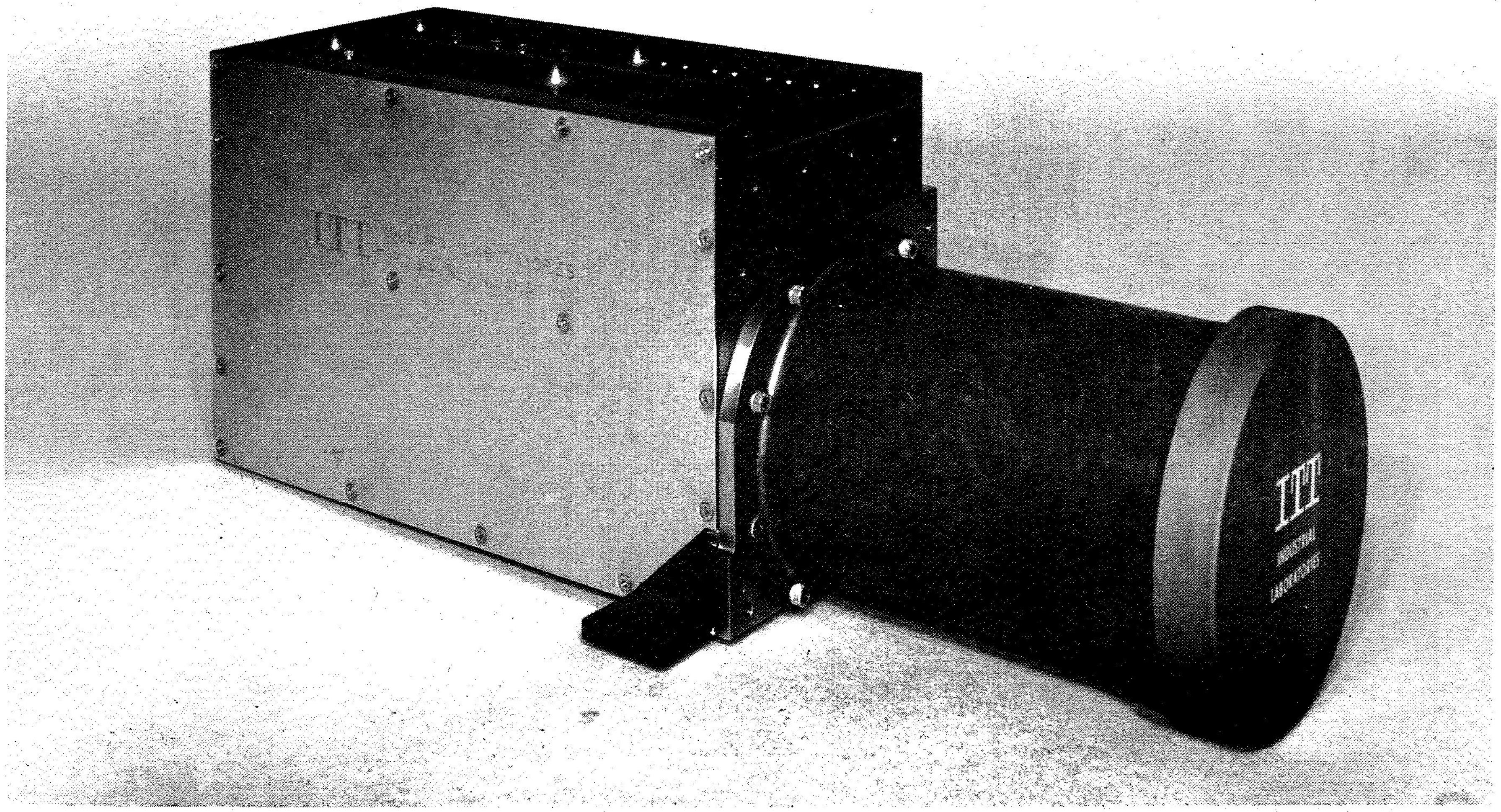


Figure 2 Camera

Electrons passing through the 0. 001 inch aperture are collected by the first of twelve photomultiplier dynodes. The electron signal from the twelfth dynode is approximately 10^7 times the aperture count. A current of 1 microampere is then caused by approximately one million electrons through the aperture for one picture element. Signal levels as low as 0. 01 microampere from the Vidissector are amplified and level shifted to provide signals to the spacecraft recorder. The subsystem is controlled by the Nimbus clock 2400 hz output.

Figure 3 shows the subsystem block diagram. Deflection circuitry is controlled by ripple counter operated digital to analog converters with considerable smoothing of the line generator output and no smoothing of the frame generator output. Logic circuits in the line and frame counters also provide frame timing signals. Two dc to dc converters are employed; one as the source of -250 volts dc and -1350 volts dc for the Vidissector tube, the other as the source of all lower voltages.

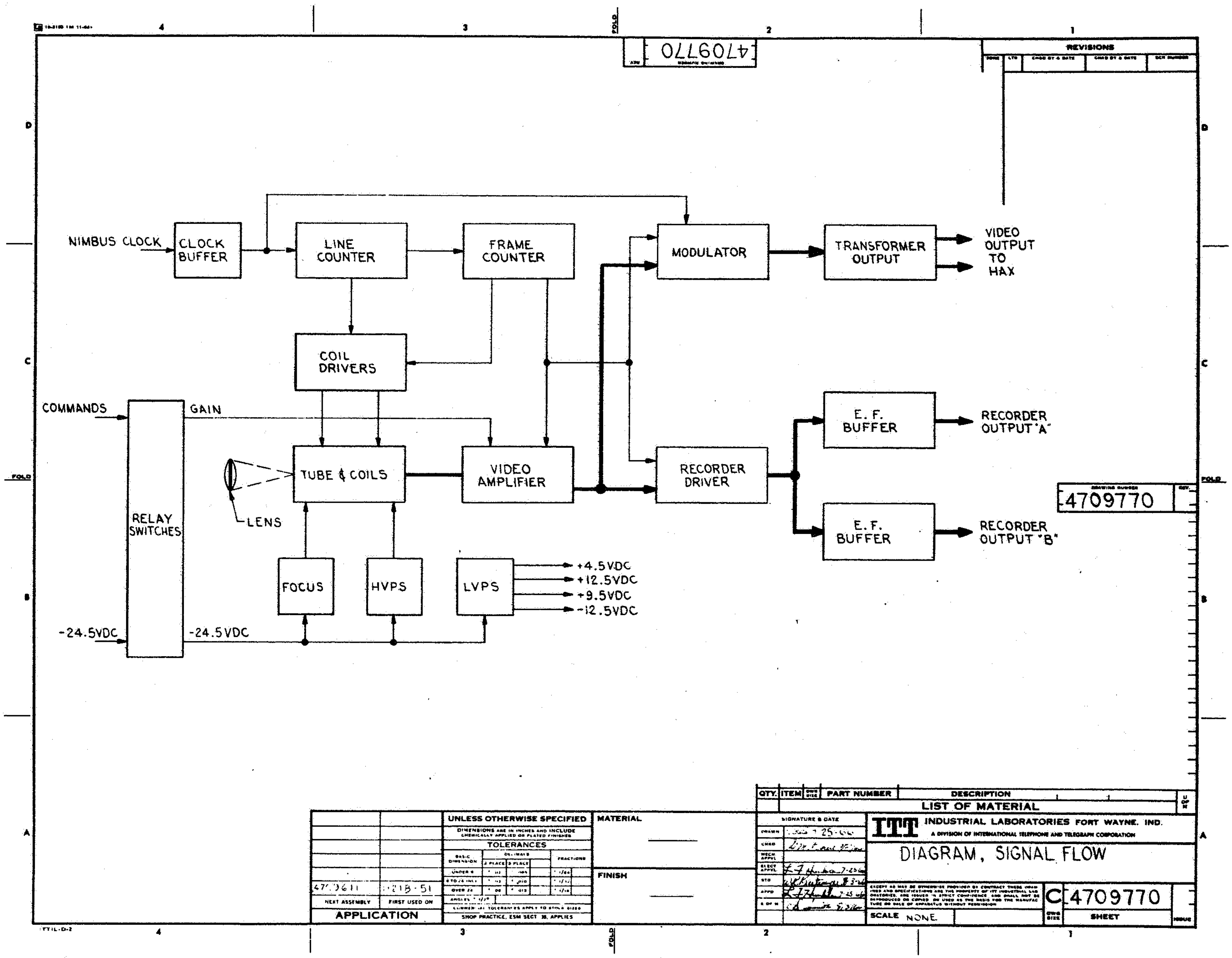
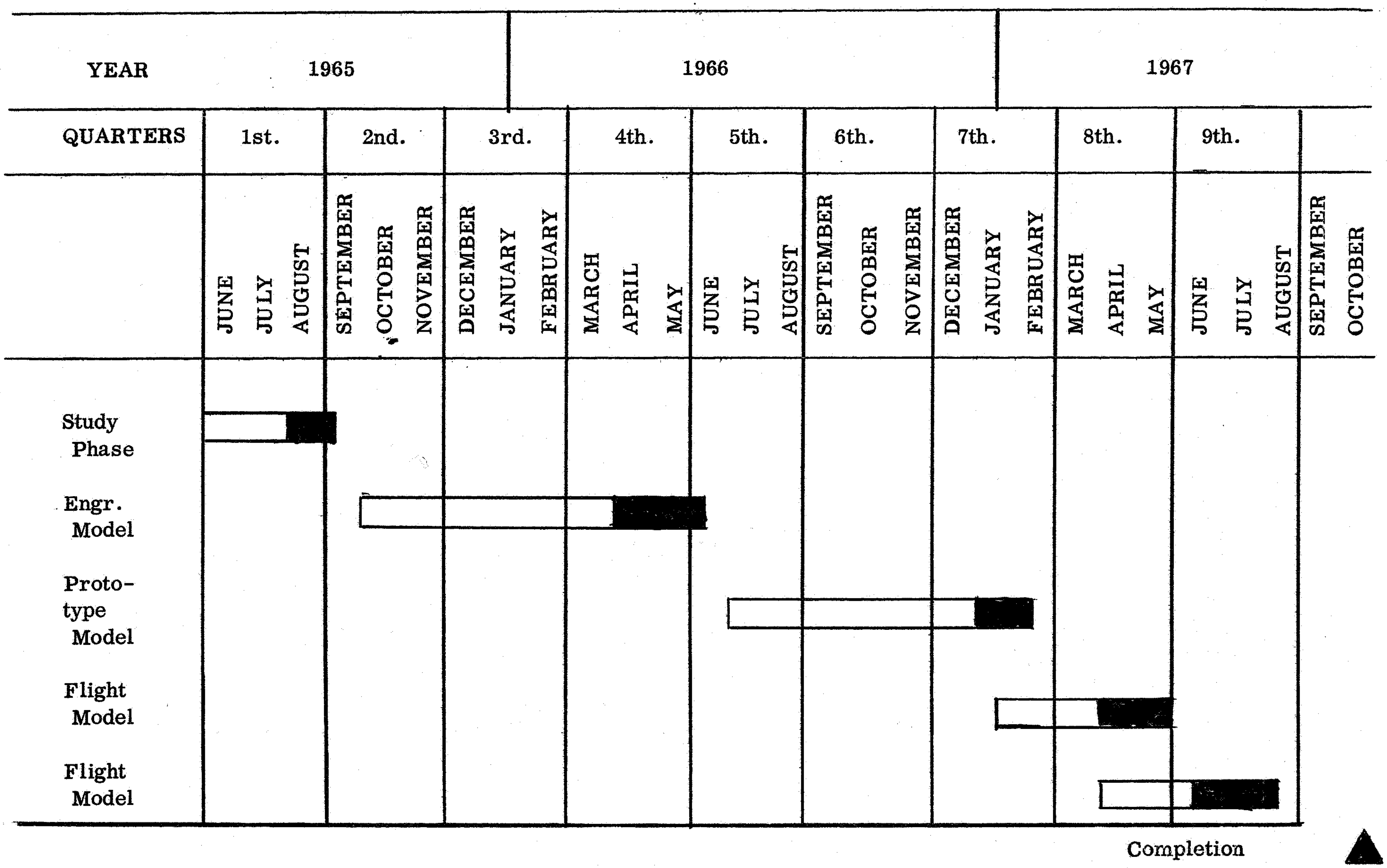

NIMBUS CLOCK
CLOCK BUFFER
LINE COUNTER
FRAME COUNTER
MODULATOR
TRANSFORMER OUTPUT
VIDEO OUTPUT TO HAX
COIL DRIVERS
COMMANDS
GAIN
RELAY SWITCHES
TUBE & COILS
VIDEO AMPLIFIER
RECORDER DRIVER
E. F. BUFFER
RECORDER OUTPUT 'A'
E. F. BUFFER
RECORDER OUTPUT 'B'
LENS
FOCUS
HVPS
LVPS
+4.5VDC
+12.5VDC
+9.5VDC
-12.5VDC
-24.5VDC
-24.5VDC
4709770
REVISIONS
LIST OF MATERIAL
ITT INDUSTRIAL LABORATORIES FORT WAYNE, IND.
A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
DIAGRAM, SIGNAL FLOW
C 4709770
SCALE NONE
SHEET
UNLESS OTHERWISE SPECIFIED
TOLERANCES
MATERIAL
FINISH
APPLICATION
NEXT ASSEMBLY
FIRST USED ON

Figure 3

FIGURE 4

Resulting Program Status Chart



3.0 STUDY PHASE

The initial 3 month study effort under this contract resulted in the Phase I Study Report on an Image Dissector Camera System dated September 30, 1965. The report presented a general plan for the optics and sensor, camera circuitry, components to be used, packaging techniques, environmental effects on life and expected results in camera parameters.

Predictions from the study phase indicated the following system characteristics may be achieved:

Resolution	25% at 830 elements/line
Shading	±15% sensor and lens
Signal/Noise	39.3 db at 10,000 F. L.
Signal/Noise	19.3 db at 100 F. L.
Geometric Distortion	1% excluding lens
Gray Scale Linearity	13 logarithmic ($\sqrt{2}$) steps 13 $\sqrt{2}$ steps (100 to 1)

One problem considered extensively during the study period involved automatic gain control (AGC). The scene illumination varies as a function of the angle between the sun and a perpendicular to the earth's surface. This variation necessitated some type of gain variation and the following types were considered:

a. Logarithmic gain

b. Scene sensor (light meter type)

c. Video peak detection with a 5 minute time constant

d. Programmed gain for each frame

e. Continuous gain variation controlled by a sun angle sensor. (sun paddle potentiometer)

The latter automatic gain control method was selected and is used with a cosine potentiometer developing the control voltage. This voltage varies from minimum at high noon to maximum at midnight (Spacecraft orbit time) and provides an increase in gain of 19.1 near the earth poles over the gain at the equatorial frame.

Automatic gain control is the normal mode of operation for the IDCS. A back-up mode is available and is initiated with a ground station command.

The mode is preset gain and fixes the gain for maximum signal with 8200 foot lamberts, which is the expected scene illumination during the pictures adjacent to the equatorial pictures.

Three applications of gain were considered:

a. Changing the iris of the lens

b. Varying the high level Vidissector dynode voltages

c. Changing the video amplifier gain

The most reliable controller and the method employed was the latter which is non-mechanical and involves low voltage circuitry.

During the study phase all aspects of the camera were covered:

a. Preamplifier and blanking signals

b. Gain control applications

c. Timing signals

d. Sweep generators

e. Modulator

f. Sun Shutter

g. Power supplies

h. Focus current regulator

i. Telemetry

j. Packaging

k. Materials

l. Radiation shielding

m. Grounding

n. Components

o. Reliability estimates

It should be mentioned that space radiation levels placed most stringent requirement on the selection of components and packaging methods.

3.1 Engineering Model (EM01)

Prior to this point of the program a completely integrated camera system had not been attempted. The engineering model was the first unit and was completed in May 1966, with the following system characteristics:

Resolution Center	18.3% at 800 TV Lines
Resolution left/right edge	6% left/2.4% right at 600 TV Lines
Shading	±37%
Signal/Noise	41.0 db at 10,000 F. L.
Signal/Noise	21.3 db at 100 F. L.
Linear Gray Scale Range	12 Shades (83 to 1)
Power Input	14 Watts

Poor resolution was attributed to a magnetic material used in the sensor for ruggedization purposes. The material eventually used, Tuphet, improved later model camera resolution and achieved the goals in ruggedization.

Circuit changes incorporated into the engineering model consisted mainly of the addition of clamp diodes to the digital-to-analog switches used in sweep generation to provide uniform step changes. Originally, DTL flatpack elements were to be used, however selection of matched units for similar switch saturation voltage was difficult and matching switch source resistances was impossible. The clamp diodes were added with minimum printed-circuit board changes, and it was decided that later models would contain inverted mode switches.

Picture frame size and centering controls were added to both the vertical and horizontal circuits, and signal non-linearity through the modulator was improved by increasing a diode bias current. The engineering model was turned on during the first week of April 1966 with an inrush current of 20 amperes. This necessitated the addition of a 10 millihenry inductor in the -24.5 volt dc input load. This inductor served an additional function in that it filtered dc to dc power supply chopper noise from the camera being conducted to the simulated -24.5 volt dc spacecraft power bus. The addition of the 2 ohm, 10 millihenry inductor reduced the operating voltage of the camera circuitry by 1 volt and therefore new transformers for the power supply converters were required.

Non-qualified components used in the engineering model caused several problems, particularly in the area of capacitor failures. An overvoltage circuit was devised to add series resistance to the 24.5 volt dc power bus for input voltages that rise above 27 volts dc. This, however, did not completely eliminate failures, for a capacitor located in the modulator developed a 200 ma leak and a RFI filter in the low voltage power supply shorted. These components were replaced and it was later determined they were inferior.

Pictures taken with the (EM01) camera were analyzed and considerable grey scale non-linearity was noted. The tube was changed with the same picture results. The Farrand grey scale reticle was questioned and replaced with Wratten neutral density filters, with no improvement. The problem was not solved in the first deliverable camera. Improvement came in the prototype model when a diode in the modulator video signal was discovered to be operating in a non-linear region. The diode was eliminated.

The engineering model IDCS was delivered to NASA at General Electric, Valley Forge, Pennsylvania on June 13, 1966 for spacecraft installation and tests.

3.2 Prototype Model (PR02)

During the engineering model testing period the prototype model housing was being machined. The previous model was constructed of aluminum, however beryllium was used for the final models. Machining for the prototype was accomplished in a special isolated fabrication area with all appropriate safety precautions. Brazing was done at Brush Beryllium and final machining at Pioneer Astro Corporation in Chicago. The final method of assembly resulting in a 50 percent filled torch brazed with aluminum-silicon alloy. Full details of this development can be found in a referenced report.*

With the existence of our first model camera the results of sensor shortcomings could easily be seen and improvements were necessary. Resolution was improved by using non-magnetic metals for internal tube construction. Underlay methods for cathode materials were improved and tested. Forty Vidissectors were constructed, however peeling aluminum causing internal shorts, wrinkled mesh, matted cathode, double apertures and inconsistent cathode sensitivity caused rejection of the majority of these tubes for prototype usage. All of these problems were generally eliminated and the best of this lot was selected for the prototype assembly.

Tests indicated that the phase margin for the focus regulator was insufficient. An R-C log network was added which gave sufficient stability. The final selection of a maximum gain figure of 19.1 with 520 foot-lamberts high light brightness was decided upon and component values were selected for this gain. DC to dc converter positive start circuitry was added to the low voltage converter. Since the high voltage converter was completed and encapsulated, the change was impractical for this unit, but all later converters contain the starting circuit.

* Reference 13

During November and December of 1966, techniques for alignment, signal level tailoring and temperature cycling were developed. While performing an initial temperature test on the camera, a failure occurred at high temperature. The cause of the failure was found to be due to one flatpack lead coming unsoldered from the printed-circuit board. After resoldering the lead by hand, a second temperature cycle was made. Again at high temperature a flatpack lead came loose from the circuit board. Both flatpack leads involved were soldered to the wiring side of the board which necessitated two 90 degree bends in the lead just prior to the point on the lead which is soldered to the board. The decision was then made to resolder by hand all flatpack connections to assure reliable connections to the boards. Prior to this problem, a Weltek model 700 Polytronic Welder was used exclusively in soldering flatpack components.

Another major problem developed when two transistor failures occurred in the low voltage power supply. The cause of the failure was found to be an assembly error. A metallic spacer, used to space the printed-circuit board away from the power supply case, was not properly positioned and was bearing on printed circuitry. Solithane conformal coating provided insulation initially, but in time, a short developed which caused the transistor failure. Proper positioning of the spacer within the assembly corrected this problem.

Prototype qualification testing began December 24, 1966 and was completed February 4, 1967. These tests were conducted without failure or adjustments of any nature. System characteristics are as follows:

Resolution Center	33% at 800 line resolution
Resolution Left/Right	9% left/16% right at 600 line resolution
Shading	±15% - with lens
Signal/Noise	37.0 db at 10,000 F. L.
Signal/Noise	19.3 db at 100 F.L.
Linear Gray Scale Range	13 Shades (100 to 1)
Input Power	12.5 Watts

3.3 Flight Model One (FT03)

With the delivery of the prototype camera to NASA at General Electric, the first flight model camera was in a pre-constructed state. Alignment and signal tailoring began in March 1967. Following initial testing, and during the temperature curing cycle of the conformal coating used throughout the camera, a falling-off of resolution was noted. Investigations proved that the optical focus changed with hot temperatures and was a result of cushioning material movement on each end of the sensor tube.

The material near the cathode end of the sensor was changed from BTR (rubber) to nylon. The sensor mounting subassembly was then temperature cycled prior to placement into the camera and remained stable after the first temperature cycle. Vibration qualification proved out the new mounting technique prior to use in both flight model cameras.

Acceptance testing for the first flight model began April 3, 1967 and was aborted on April 7 with a vibration failure. The problem involved a weld in the photomultiplier section of the sensor. The irony was this sensor had shown the least shading to date of all flight worthy Vidissectors and that resolution was 31/40/57 percent modulation for left/center/right picture resolution. With the Vidissector replaced, acceptance testing began the second time on April 28 and was completed May 30.

During acceptance testing, at the conclusion of the thermal vacuum test, the camera was removed from the chanber. The prolonged exposure of the camera to a fixed test pattern was evidenced by a noticeable amount of image retention. Also, after rechecking the calibration of the collimator, it was found that the tube sensitivity had decreased 40 percent. A complete bench test disclosed no other changes. Rather than replace the tube again, it was decided that additional tube aging should be done to see if its sensitivity would stabilize. This was done on a 24 hour-a-day basis for a period of a week. The retained image disappeared within minutes after the start of the aging. Sensitivity continued to drop during the first day but then became quite stable. Over the final 5 days of the test the sensitivity remained stable and it was decided that no tube change was necessary, however, adjustment of video gain was necessary.

A short bench test was then performed after which the camera was given a workmanship vibration test. The final acceptance test was performed and the FT03 camera was accepted on May 31.

The final system characteristics were:

Resolution Center	40% at 800
Resolution left/right edges	40/25% at 600
Shading	±15.6% with lens
Signal/Noise	36 db at 10,000 F. L.
Signal/Noise	20 db at 100 F. L.
Geometric Distortion	1.7%
Linear Gray Scale Range	13 Shades (100:1)
Power Input	11.03 Watts

On July 26, during the assembly of the second flight model camera, it was discovered that the Tegea lens received to date did not contain a minus blue filter. This came to light when in discussion with the vendor (lens), they inquired if filters were desired on the lens order for the "NIMBUS D" program, since a filter was not included in our previous orders. This, to say the least, shocked everyone involved with procurement.

The lens originally intended for FT04 was then sent to the NASA representative at AED, RCA, Princeton, N. J. where a filter was installed. Meanwhile FT03 was returned to ITTIL Fort Wayne, for lens changing. The lens was changed, the camera tested, vibrated (workmanship level), retested and returned to NASA at General Electric, Valley Forge, Pa. The lens change had no effect on system characteristics.

3.4 Flight Model (FT04)

Construction of the final IDCS was completed in June 1967. Following pre-acceptance adjustments the camera was subjected to 62 hours of operation while viewing a scene of 7500 foot lamberts light level. The purpose of this test was to determine the photocathode sensitivity stability. The resultant change was -3 percent, probably within the accuracy limits of measurements techniques.

Acceptance testing began on June 15 and was aborted after 14 hours at high vacuum on June 24. The failure appeared as a 7 percent increase in 24.5 volts dc input current along with no video signal and a 7 percent decrease in the high voltage telemetry.

Several trouble-shooting tests were required both in and out of the vacuum chamber before the problem was definitely established as being the high voltage resistor assembly potted to the pin end of the Vidissector; specifically due to a critical pressure distance product condition inside a 3.9 megohm resistor. The core of the resistor contained air that became a gaseous conductor, with the critical pressure point being a function of the air leak rate through RTV 3110 encapsulating compound.

The question remained, why did the problem show up in only the third qualifying model? This question was answered when it was determined that the potting cure cycle had been altered allowing a fast air leak rate. The assembly was then cleaned and repotted using an improved cure cycle and testing resumed. The problem did not reappear. A similar assembly under high vacuum, has been operating continuously without incident for 10 weeks at the time of this writing.

The final camera was accepted on August 18, 1967 and delivered to General Electric at Valley Forge, Pennsylvania.

Final system characteristics were:

Resolution Center	33%
Resolution left/right edges	28/49%
Shading	± 17% with lens
Signal to Noise	38 db at 10,000 F. L.
Signal to Noise	18.4 db at 100 F. L.
Geometric Distortion	1%
Gray Scale Linearity	13 Shades (100 to 1)
Power Input	12 Watts
Weight	13.19

3.5 High Voltage Problem

As mentioned in Section 3.4, during acceptance testing of the last deliverable camera serial number FT04, developed under Contract Number NAS5-9619, trouble occurred during thermal vacuum testing on June 24, 1967. A reworked high voltage divider network to eliminate a high voltage breakdown problem resulted in an acceptable camera, FT04 that was delivered on August 18, 1967.

A duplicate tube, high voltage divider circuit and coil assembly also began undergoing an extended vacuum test on August 18, 1967. This duplicate unit failed and recovered October 27, 1967. The failure was determined to be caused by the leak of entrapped air from a hollow 3.9 megohm resistor in the potted high voltage divider which inevitably resulted in the pressure-distance product according to Paschen's law, within the resistor body becoming critical, with respect to its permitting a spark breakdown to occur across its terminals. Approximately 1 kilovolt is normally across this resistor. The problem was believed solved by changes to the potting cure cycle which enabled the potted divider to show no evidence of failure during a 12 day thermal vacuum test, as opposed to the failure occurring within 14 hours as had happened previously. It was then concluded after the duplicate unit (to FT04) had failed that the leak rate of air within the hollow resistor had been slowed considerably but not sufficiently to meet the specification of 6 months operation in the high vacuum environment of space.

Obviously, the solution to the problem was to eliminate the possibility that a critical pressure-distance product could occur. Several alternatives were considered: (1) procure a hermetically sealed high voltage resistor to replace the 3.9 megohm resistor manufactured by Resistor Products Corporation (RPC), (2) obtain, if possible, resistors from RPC identical to the BAEW type except that they be made with solid ceramic bodies instead of hollow ceramic bodies, and (3) filling the void in the hollow BAEW type resistors with the same potting compound (DOW RTV 3110) used to encapsulate the divider.

The first alternative resulted in the selection of a hermetically sealed Pyrofilm HV resistor. A divider was built and subsequently passed vibration tests in a potted tube and coil assembly. However, several considerations resulted in this method being rejected; the fact that a very minute leak of the entrapped nitrogen within the unit could result in a failure some time in a vacuum environment and the fact that a full qualification test of the IDCS would be required to prove the suitability of this resistor in the encapsulated high voltage divider. The second alternative resulted in RPC undertaking the construction of solid ceramic resistor bodies. However, this was rejected because of the time required to obtain delivery of the modified resistors. The third alternative, using resistors which are filled with RTV 3110, was adopted as the most expeditious, economical and suitable solution to the problem since prior qualification tests would still apply. Even assuming a predictable 4 percent shrinkage of the potting during curing within the resistor body, which is substantially reduced when the end caps are screwed into the ceramic body, the volume of entrapped air is greatly reduced. Then, even if the previous pressure-distance product should apply, which is highly unlikely, the unchanged leak rate would result in a considerable shortening of the time scale on the exponential internal pressure versus time curve for the resistor. (See Figure 5.) This exponential curve is characteristic of any vessel having a given volume, and a leak rate proportional to both the instantaneous internal to external pressure differential and the effective orifice area. Since the effective orifice area through which entrapped air could escape had been reduced as much as possible by optimizing the curing process of the potting and the initial pressure differential of one atmosphere from earth to orbit could not be changed, volume was the only time dependent variable which could be changed, (i. e.) the pressure volume product should be made a minimum.

This shortened time scale reduced, as shown in Figure 5, the time to reach and pass through the critical pressure region where spark breakdown could occur.

A duplicate tube, high voltage divider and coil assembly incorporating the "filled" resistor began extended vacuum testing on November 27, 1967. As of December 26, no evidence of failure has been observed.

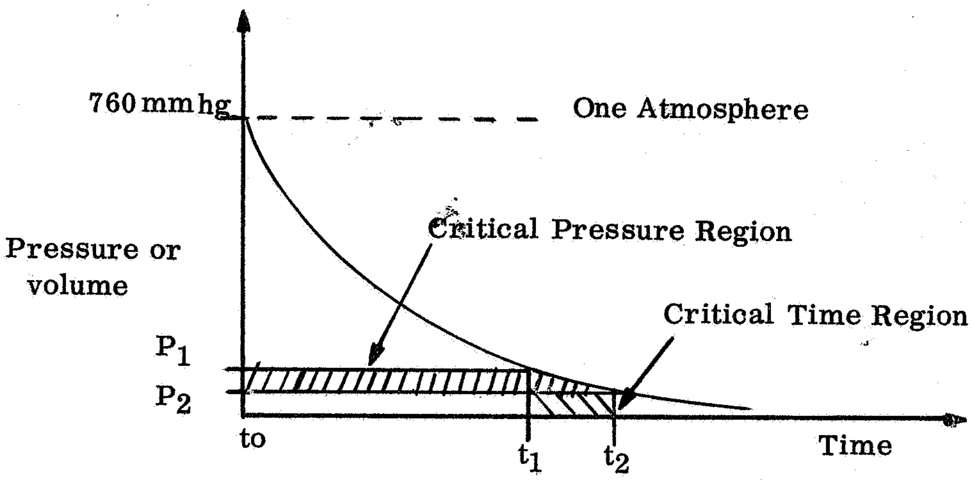


Figure 5

t_1	=	time to reach spark breakdown (P_1d)
t_2	=	time to pass through spark breakdown (P_2d)
d	=	distance between electrodes (a constant)
V	=	volume; considered a constant
T	=	temperature; considered a constant

IDCS serial number FT03 was returned to ITTIL from GE on November 2 to have filled resistors incorporated in the high voltage divider assembly. On November 7 after tube potting and cure cycle was completed, new spots were observed on the photocathode of the image dissector tube. The tube was rotated in an unsuccessful attempt to remove them from the scanned area. The tube was then rotated so as to minimize the effect of the new spots. A 56 hour thermal vacuum test was begun on November 11. A workmanship vibration test was performed at GSFC on November 15. Qualification tests were completed on November 17 and IDCS FT03 was returned to GE at Valley Forge.

The remaining deliverable IDCS, FT04 was returned to ITTIL from GE on November 28 to have "filled" resistors added to the high voltage divider. FT04 was returned to GE at Valley Forge on December 19.

The work done on both FT03 and FT04 described in the preceding paragraphs was done under the Nimbus B Integration Contract, Number NAS5-10155.

4.0 CAMERA CHARACTERISTICS SUMMARY

	Required	Engineering Mod (EM01)	Prototype (PR02	Flight (FT03)	Flight (FT04)
Recorder Output Levels					
Front Porch	-6.50V	-6.41	-6.64	-6.53	6.6
Sync Step	-8.0V	-8.0	-8.12	-8.02	8.15
Back Porch	--	-6.46	-6.60	-6.60	6.58
White Level	-4.3V	-4.3	-4.3	-4.3	4.3
Modulator Output					
Sync Pulses (7)	2.8VP-P	2.75	2.80	2.78	2.85
Black Level	70MVP-P	70	75	72	75
Resolution					
Center (800 TV Lines)	25%	18.3%	33%	39%	33%
Left/Right Edge (600 TV Lines)	20%	6/2.4%	9/16%	31/57%	28/49%
Signal/Noise					
100 Foot Lamberts	20db	21.3db	19.3db	19db	18.4db
1000 Foot Lamberts	40db	41.0db	37.0db	39db	38.0db
Input Current					
Surge (Max)	1.2 Amps	1.3Amps	1.0Amps	0.82Amps	0.84Amps
Surge Rate (Max)	2.0A/MS	1.5A/MS	1.67A/MS	1.65A/MS	1.8A/MS
Nominal	530ma	560ma	500ma	450ma	485ma
Linear Gray Scale Range	13 Shades	12 Shades	11 Shades	13 Shades	13 Shades
Shading with Lens	±5%	±37%	±15%	±17%	±17%
Weight		N/A	13.0 lbs.	13.1 lbs.	13.19 lbs.

5.0 LIST OF RELATED REPORTS AND DOCUMENTS

1. Final Report of a Study to Investigate the Feasibility of a Continuous Mapping Camera System; Contract Number NAS5-3770; November 13, 1964.

2. Technical Proposal for a Continuous Mapping Camera, November 4, 1964.

3. Technical Proposal for a Continuous Scanning Meteorological Camera Subsystem, March 15, 1965.

4. Technical Proposal for Image Dissector Camera Subsystem Integration Support and Initial Integration of the Real Time Transmission System, December 17, 1965.

5. Phase I Study Report on an Image Dissector Camera System, Contract Number NAS5-9619, September 30, 1965.

6. First Six Months Report for Integration Support for IDCS into Nimbus Satellite; Contract Number NAS5-10155, October 17. 1966.

7. Report for Real Time Transmission of the IDCS and HRIR Engineering Models; Contract Number NAS5-10155, July 7, 1966.

8. Instruction Manual for Nimbus IDCS Bench Check Unit; Contract Number NAS5-9619, July 14, 1967.

9. Investigation of Geometrical Relationships of the Image Dissector Camera for Nimbus B, Contract Number NAS5-10155, May 22, 1967.

10. Twenty Monthly Reports; Contract Number NAS5-9619, December 10, 1966 to August 10, 1967.

11. Nine Quarterly Reports; Contract Number NAS5-9619, September 22, 1965 to October 1967.

12. Operations and Maintenance Manual for the Nimbus B Image Dissector Camera System; Contract Number NAS-9619, October 1967.

13. Designing With Beryllium; by James D. Crawford, ITT Industrial Laboratories No. 67-03.

14. Environmental Test Plan for IDCS Prototype and Flight Models, ITT No. 4709786, February 21, 1967.